

Table of Contents

1.	Identification Page.....	1
2.	Table of Contents	2
3.	Real Party in Interest	3
4.	Related Appeals and Interferences	4
5.	Status of Claims	5
6.	Status of Amendments	6
7.	Summary of Claimed Subject Matter	7
8.	Grounds of Rejection to be Reviewed on Appeal	11
9.	Arguments	12
10.	Conclusion	25
11.	Claims Appendix	26
12.	Evidence Appendix	40
13.	Related Proceedings Appendix	41

Real Party in Interest

The present application has been assigned to Applied Materials, Inc., 3050 Bowers Avenue, Santa Clara, California 95054.

Related Appeals and Interferences

Applicant asserts that no other appeals or interferences are known to the Applicant, the Applicant's legal representative, or assignee which will directly affect or be directly affected by or have a bearing on the Board's decision in the pending appeal.

Status of Claims

Claims 1, 2, 4-7, 9-14, 16, 17, 19, 20, 22-25, 27, 28, 30-33, 35-38, 40-42, 44-46, 48-51, and 53-67 are pending in the application. Claims 1-55 were originally presented in the application. Claims 56-67 were added in Applicants' Response to Office Action dated January 14, 2008. Claims 3, 8, 15, 18, 21, 26, 29, 34, 39, 43, 47, and 52 have been canceled without prejudice. Claims 1, 2, 4-7, 9-14, 16, 17, 19, 20, 22-25, 27, 28, 30-33, 35-38, 40-42, 44-46, 48-51, and 53-67 stand finally rejected as discussed below. The final rejection of claims 1, 2, 4-7, 9-14, 16, 17, 19, 20, 22-25, 27, 28, 30-33, 35-38, 40-42, 44-46, 48-51, and 53-67 is appealed. The pending claims are shown in the attached Claims Appendix.

Status of Amendments

All claim amendments have been entered by the Examiner. No amendments to the claims were proposed after the final rejection. The response filed July 8, 2008 after the final rejection was entered and did not amend the claims.

Summary of Claimed Subject Matter

Claimed embodiments of the invention provide a method of forming a ruthenium material on a substrate surface (p. 18, paragraph [0059], lines 1-2; Figure 4).

In the embodiments of independent claim 1, a method of forming a ruthenium material on a substrate surface (p. 18, paragraph [0059], lines 1-2; Figure 4) comprising positioning a substrate within a process chamber (p. 18, paragraph [0059], lines 3-4; Figure 4), exposing a ruthenium-containing compound to the substrate while forming a ruthenium-containing compound film thereon (p. 19, paragraph [0062], lines 1-3; Figure 4), wherein the ruthenium-containing compound is selected from the group consisting of bis(dialkylpentadienyl) ruthenium compounds, bis(alkylpentadienyl) ruthenium compounds, bis(pentadienyl) ruthenium compounds, and combinations thereof (p. 20, paragraph [0064], lines 10-12; Figure 4), purging the process chamber with a purge gas (p. 22, paragraph [0066], lines 13-15; Figure 4), exposing a reducing gas comprising ammonia and atomic hydrogen to the ruthenium-containing compound film on the substrate while forming a ruthenium layer thereon (p. 22, paragraph [0067], line 1 – P. 23, paragraph [0068], line 6; Figure 4), and purging the process chamber with the purge gas (p. 24, paragraph [0079], lines 1-3; Figure 4) is provided.

In the embodiments of independent claim 11, a method of forming a ruthenium material on a substrate surface (p. 18, paragraph [0059], lines 1-2; Figure 4) comprising exposing a substrate to bis(2,4-dimethylpentadienyl) ruthenium to form a ruthenium-containing film on the substrate (p. 19, paragraph [0062], lines 1-3; p. 20, paragraph [0064], lines 10-12; Figure 4), purging the process chamber with a purge gas, exposing a reducing gas comprising ammonia to the ruthenium-containing film while forming a ruthenium layer thereon (p. 22, paragraph [0066], lines 13-15; Figure 4), and purging the process chamber with the purge gas (p. 24, paragraph [0079], lines 1-3; Figure 4) is provided.

In the embodiments of independent claim 19, a method of forming a ruthenium material on a substrate surface (p. 18, paragraph [0059], lines 1-2; Figure 4) comprising

depositing a barrier layer on a substrate during a first ALD process, wherein the barrier layer comprises a material selected from the group consisting of tantalum, tantalum nitride, tantalum silicon nitride, titanium, titanium nitride, titanium silicon nitride, tungsten, tungsten nitride, and combinations thereof (p. 29, paragraph [0085], line 1 – p. 30, paragraph [0086], line 12; Figure 5A-5C) and exposing the substrate sequentially to a ruthenium-containing compound and a reducing gas comprising ammonia to form a ruthenium layer on the barrier layer during a second ALD process, wherein the ruthenium-containing compound is selected from the group consisting of bis(dialkylpentadienyl) ruthenium compounds, bis(alkylpentadienyl) ruthenium compounds, bis(pentadienyl) ruthenium compounds, and combinations thereof (p. 19, paragraph [0062], lines 1-3; p. 20, paragraph [0064], lines 10-12; Figure 4) is provided.

In the embodiments of independent claim 27, a method of forming a ruthenium material on a dielectric material formed on a substrate surface (p. 18, paragraph [0059], lines 1-2; Figure 4) comprising positioning a substrate comprising a dielectric layer thereon within a process chamber (p. 18, paragraph [0059], lines 3-4; Figures 4 and 5A-5C), exposing a ruthenium-containing compound to the dielectric layer while forming a ruthenium-containing compound film thereon (p. 19, paragraph [0062], lines 1-3; Figure 4), wherein the ruthenium-containing compound is selected from the group consisting of bis(dialkylpentadienyl) ruthenium compounds, bis(alkylpentadienyl) ruthenium compounds, bis(pentadienyl) ruthenium compounds, and combinations thereof (p. 20, paragraph [0064], lines 10-12; Figure 4), purging the process chamber with a purge gas (p. 22, paragraph [0066], lines 13-15; Figure 4), exposing a reducing gas comprising ammonia to the ruthenium-containing compound film on the dielectric layer while forming a ruthenium layer thereon (p. 22, paragraph [0067], line 1 – P. 23, paragraph [0068], line 6; Figure 4), and purging the process chamber with the purge gas (p. 24, paragraph [0079], lines 1-3; Figure 4) is disclosed.

In the embodiments of independent claim 36, a method of forming a ruthenium material on a substrate surface (p. 18, paragraph [0059], lines 1-2; Figure 4) comprising positioning a substrate within a process chamber (p. 18, paragraph [0059], lines 3-4; Figures 4 and 5A-5C), exposing the substrate to a ruthenium-containing compound

comprising ruthenium and at least one open chain dienyl ligand while forming a ruthenium-containing compound film thereon (p. 20, paragraph [0064], lines 10-12; Figure 4), purging the process chamber with a purge gas (p. 22, paragraph [0066], lines 13-15; Figure 4), exposing the ruthenium-containing compound film to a reducing gas comprising ammonia and hydrogen gas while forming a ruthenium layer on the substrate (p. 22, paragraph [0067], line 1 – P. 23, paragraph [0068], line 6; Figure 4), and purging the process chamber with the purge gas (p. 24, paragraph [0079], lines 1-3; Figure 4) is disclosed.

In the embodiments of independent claim 44, a method for forming a ruthenium material on a low-k material disposed on a substrate surface (p. 29, paragraph [0085], lines 1-14; Figures 5A-5C) comprising positioning a substrate comprising a low-k layer disposed thereon within a process chamber (p. 29, paragraph [0085], lines 1-14; Figures 5A-5C), heating the substrate to a temperature within a range from about 200°C to about 400°C (p. 33, paragraph [0094], lines 1-2; Figures 5A-5C), exposing the low-k layer to a ruthenium-containing compound comprising ruthenium and at least one open chain dienyl ligand while forming a ruthenium-containing compound film thereon (p. 20, paragraph [0064], lines 10-12; Figure 4), purging the process chamber with a purge gas (p. 22, paragraph [0066], lines 13-15; Figure 4), exposing the ruthenium-containing compound film to a reducing gas comprising ammonia while forming a ruthenium layer on the low-k layer (p. 22, paragraph [0067], line 1 – P. 23, paragraph [0068], line 6; Figure 4), and purging the process chamber with the purge gas (p. 24, paragraph [0079], lines 1-3; Figure 4) is disclosed.

In the embodiments of independent claim 54, method for forming a ruthenium material on a low-k material disposed on a substrate surface (p. 29, paragraph [0085], lines 1-14; Figures 5A-5C) comprising positioning a substrate comprising a low-k layer disposed thereon within a process chamber (p. 29, paragraph [0085], lines 1-14; Figures 5A-5C), heating the substrate to a temperature within a range from about 200°C to about 400°C (p. 33, paragraph [0094], lines 1-2; Figures 5A-5C), exposing the low-k layer to bis(2,4-dimethylpentadienyl) ruthenium to form a ruthenium-containing compound film thereon (p. 20, paragraph [0064], lines 10-12; Figure 4), purging the

process chamber with a purge gas (p. 22, paragraph [0066], lines 13-15; Figure 4), exposing the ruthenium-containing compound film to a reducing gas comprising ammonia and atomic hydrogen while forming a ruthenium layer on the low-k layer (p. 22, paragraph [0067], line 1 – P. 23, paragraph [0068], line 6; Figure 4), and purging the process chamber with the purge gas (p. 24, paragraph [0079], lines 1-3; Figure 4) is disclosed.

In the embodiments of independent claim 55, method for forming a ruthenium material on a barrier material layer disposed on a substrate surface (p. 29, paragraph [0085], line 1 – p. 30, paragraph [0086], line 12; Figure 5A-5C) comprising positioning a substrate comprising a tantalum-containing barrier layer disposed thereon within a process chamber (p. 29, paragraph [0085], line 1 – p. 30, paragraph [0086], line 12; Figure 5A-5C), heating the substrate to a temperature within a range from about 200°C to about 400°C (p. 33, paragraph [0094], lines 1-2; Figures 5A-5C), exposing the tantalum-containing barrier layer to bis(2,4-dimethylpentadienyl) ruthenium while forming a ruthenium-containing compound film thereon (p. 20, paragraph [0064], lines 10-12; Figure 4), purging the process chamber with a purge gas (p. 22, paragraph [0066], lines 13-15; Figure 4), exposing the ruthenium-containing compound film to a reducing gas comprising ammonia and atomic hydrogen while forming a ruthenium layer on the tantalum-containing barrier layer (p. 22, paragraph [0067], line 1 – P. 23, paragraph [0068], line 6; Figure 4), and purging the process chamber with the purge gas is disclosed.

Ground of Rejection to be Reviewed on Appeal

Claims 1, 2, 4-7, 9-14, 16, 17, 19, 20, 22-25, 27, 28, 30-33, 35-38, 40-42, 44-46, 48-51, and 53-67 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over U.S. Patent Application Publication No. 2003/0165615 to *Aaltonen et al.* in view of U.S. Patent No. 6,605,735 to *Kawano et al.*

Arguments

A. *Aaltonen et al.* and *Kawano et al.* do not render claims 1, 2, 4-7, 9, 10, 19, 20, 22-25, 27, 28, 30-33, 35, 56, 57, and 60-63 obvious

Claims 1, 2, 4-7, 9, 10, 19, 20, 22-25, 27, 28, 30-33, 35, 56, 57, and 60-63 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over U.S. Patent Application Publication No. 2003/0165615 to *Aaltonen et al.* in view of U.S. Patent No. 6,605,735 to *Kawano et al.*

Aaltonen et al. discloses “placing a substrate in a reaction chamber within a reactor,” “providing a vaporized noble metal precursor into the reaction chamber to form a single molecular layer of the precursor on the substrate,” “removing excess vaporized precursor from the reaction chamber”, “providing a second reactant gas comprising oxygen to the reaction chamber such that the oxygen reacts with the precursor on the substrate,” and “removing excess reactant gas and reactant by-products from the reaction chamber.” (See paragraph [0021]). *Aaltonen et al.* performs an ALD method (See paragraph [0034]) and recognizes “the general limitations of the CVD method, such as problems related to achieving good large area uniformity and accurate thickness control” (See paragraph [0012]).

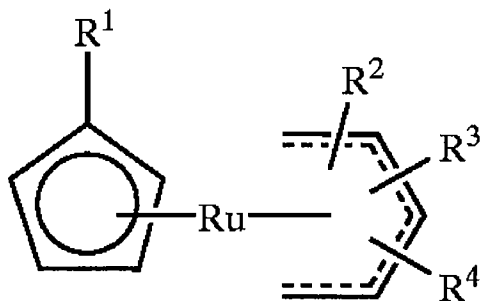
As noted by the Examiner, *Aaltonen et al.* “does not disclose the ruthenium precursors as required by claim 1,” and claims dependent thereon (See Final Office Action mailed April 8, 2008, page 4). As claims 19 and 27 each recite the same ruthenium precursors as recited in claim 1, Applicant respectfully submits that the Examiner has also implicitly agreed that *Aaltonen et al.* does not disclose the ruthenium precursors recited in claims 19 and 27 and claims dependent thereon¹.

To solve the ruthenium precursor deficiencies of *Aaltonen et al.*, the Examiner has relied upon the teaching of *Kawano et al.* *Kawano et al.*, contrary to the teachings of *Aaltonen et al.*, discloses a CVD process for forming a ruthenium-containing thin film.

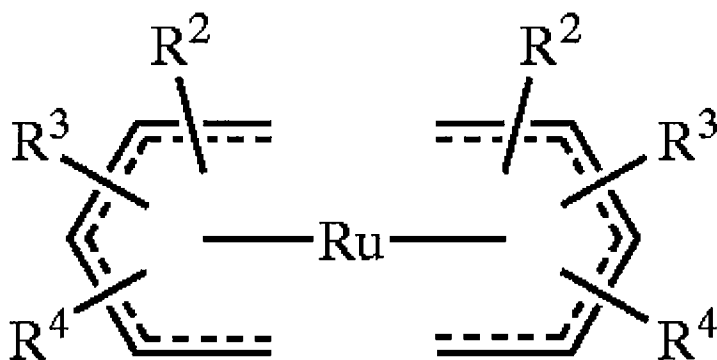
¹ Applicant respectfully notes that the Examiner has correctly recognized that bis(dialkylpentadienyl) ruthenium compounds, bis(alkylpentadienyl) ruthenium compounds, and bis(pentadienyl) ruthenium compounds do not encompass bis(cyclopentadienyl) ruthenium compounds.

(See col. 3, lines 17-22). *Kawano et al.* utilizes a half-sandwich organometallic ruthenium compound in the CVD method (See col. 7, l. 40-44). The half-sandwich organometallic ruthenium compound may be represented by the following formula:

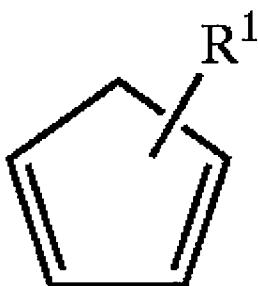
(1)



The half-sandwich organometallic ruthenium compound may be formed by “reacting an open ruthenocene...in a solvent in the presence of zinc with a cyclopentadiene...to thereby produce a half-sandwich organometallic ruthenium compound represented by the general formula (1).” (See col. 3, lines 65 – col. 4, lines 25). The open ruthenocene is represented by the following general formula:



The cyclopentadiene is represented by the following general formula:



Thus, the half-sandwich organometallic ruthenium compound precursor used in the CVD process of *Kawano et al.* also is not a bis(dialkylpentadienyl) ruthenium compound, bis(alkylpentadienyl) ruthenium compound, or a bis(pentadienyl) ruthenium compound as recited in claims 1, 19, and 27. The precursor used to synthesize the half-sandwich organometallic ruthenium compound precursor is a bis(pentadienyl) ruthenium compound, but such bis(pentadienyl) ruthenium compound is never exposed to the substrate in *Kawano et al.* Applicant respectfully submits that one of ordinary skill, when confronted with *Kawano et al.*, would utilize the half-sandwich organometallic ruthenium compound as a ruthenium precursor. Applicant respectfully submits that one of ordinary skill in the art, when confronted with *Kawano et al.*, would not utilize the bis(pentadienyl) ruthenium compound as a precursor in a deposition process. Therefore, Applicants respectfully submits that utilizing the bis(pentadienyl) ruthenium compound of *Kawano et al.* in the ALD process of *Aaltonen et al.* is not obvious.

Regarding the reducing gas, the Examiner has admitted that both *Aaltonen et al.* and *Kawano et al.* “do not explicitly teach using the combination of ammonia and atomic hydrogen as a reducing agent.” (See Final Office Action mailed April 8, 2008, page 5). The Examiner proceeds to rely upon reducing agents disclosed in Applicant’s specification by state that Applicant “admits that reducing agents such as ammonia, atomic hydrogen, etc. and combinations thereof are traditional reducing agents” (See Final Office Action mailed April 8, 2008, page 5).

Applicant’s disclosure states “[s]uitable reducing gases may include traditional reductants, for example, hydrogen (e.g., H₂ or atomic-H), ammonia (NH₃) ...” (See paragraph [0068]). Applicant respectfully submits that even if the reducing gases disclosed in Applicant’s specification are considered well known and/or traditional, one

or ordinary skill in the art would not modify *Aaltonen et al.* to utilize such reducing gases.

Aaltonen et al. is directed to utilizing oxygen containing gas as a reducing gas as opposed to any other reducing gases. *Aaltonen et al.* states:

Surprisingly we have now found that oxygen, in particular oxygen in molecular form, is capable of reducing noble metal compounds into elemental form. High, quality metal thin films can be deposited by utilizing reactions between the metal precursor and oxygen. This is surprising, since oxygen is usually considered an oxidizing source chemical in ALD and even as such an agent its reactivity is usually only modest at temperatures below 500°C.

(See paragraph [0019]). Thus, *Aaltonen et al.* teaches using a specific reducing gas. Applicant respectfully submits that changing the reducing gas of *Aaltonen et al.*, as proposed by the Examiner, would destroy the teachings of *Aaltonen et al.* Therefore, Applicant respectfully submits that the Examiner's proposed modification of *Aaltonen et al.* is not obvious.

Therefore, *Aaltonen et al.* and *Kawano et al.*, alone or in combination, do not teach, show, or suggest a method for forming a ruthenium material on a substrate surface, comprising positioning a substrate within a process chamber, exposing a ruthenium-containing compound to the substrate while forming a ruthenium-containing compound film thereon, wherein the ruthenium-containing compound is selected from the group consisting of bis(dialkylpentadienyl) ruthenium compounds, bis(alkylpentadienyl) ruthenium compounds, bis(pentadienyl) ruthenium compounds, and combinations thereof, purging the process chamber with a purge gas, exposing a reducing gas comprising ammonia and atomic hydrogen to the ruthenium-containing compound film on the substrate while forming a ruthenium layer thereon, and purging the process chamber with the purge gas, as recited in claim 1, and claims dependent thereon. Withdrawal of the rejection is respectfully requested.

Additionally, *Aaltonen et al.* and *Kawano et al.*, alone or in combination, do not teach, show, or suggest a method for forming a ruthenium material on a substrate,

comprising depositing a barrier layer on a substrate during a first ALD process, wherein the barrier layer comprises a material selected from the group consisting of tantalum, tantalum nitride, tantalum silicon nitride, titanium, titanium nitride, titanium silicon nitride, tungsten, tungsten nitride, and combinations thereof, and exposing the substrate sequentially to a ruthenium-containing compound and a reducing gas comprising ammonia to form a ruthenium layer on the barrier layer during a second ALD process, wherein the ruthenium-containing compound is selected from the group consisting of bis(dialkylpentadienyl) ruthenium compounds, bis(alkylpentadienyl) ruthenium compounds, bis(pentadienyl) ruthenium compounds, and combinations thereof, as recited in claim 19, and claims dependent thereon. Withdrawal of the rejection is respectfully requested.

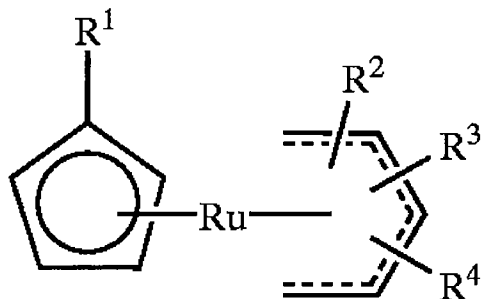
Also, *Aaltonen et al.* and *Kawano et al.*, alone or in combination, do not teach, show, or suggest a method for forming a ruthenium film on a dielectric material disposed on a substrate surface, comprising positioning a substrate comprising a dielectric layer thereon within a process chamber, exposing a ruthenium-containing compound to the dielectric layer while forming a ruthenium-containing compound film thereon, wherein the ruthenium-containing compound is selected from the group consisting of bis(dialkylpentadienyl) ruthenium compounds, bis(alkylpentadienyl) ruthenium compounds, bis(pentadienyl) ruthenium compounds, and combinations thereof, purging the process chamber with a purge gas, exposing a reducing gas comprising ammonia to the ruthenium-containing compound film on the dielectric layer while forming a ruthenium layer thereon, and purging the process chamber with the purge gas, as recited in claim 27, and claims dependent thereon. Withdrawal of the rejection is respectfully requested.

B. *Aaltonen et al.* and *Kawano et al.* do not render claims 11-14, 16, 17, 54, 55, 58, 59, and 67 obvious

Claims 11-14, 16, 17, 54, 55, 58, 59, and 67 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over U.S. Patent Application Publication No. 2003/0165615 to *Aaltonen et al.* in view of U.S. Patent No. 6,605,735 to *Kawano et al.*

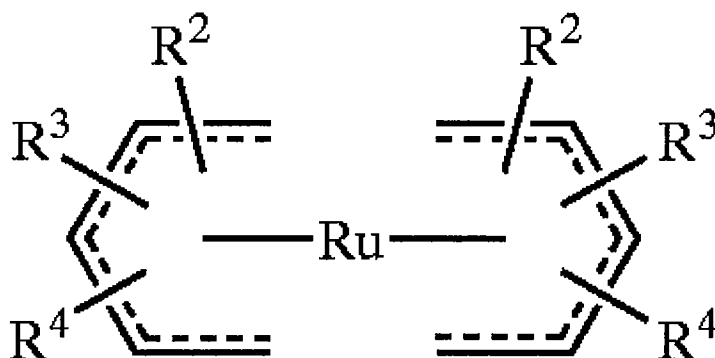
Aaltonen et al. discloses "placing a substrate in a reaction chamber within a reactor," "providing a vaporized noble metal precursor into the reaction chamber to form a single molecular layer of the precursor on the substrate," "removing excess vaporized precursor from the reaction chamber", "providing a second reactant gas comprising oxygen to the reaction chamber such that the oxygen reacts with the precursor on the substrate," and "removing excess reactant gas and reactant by-products from the reaction chamber." (See paragraph [0021]). *Aaltonen et al.* performs an ALD method (See paragraph [0034]) and recognizes "the general limitations of the CVD method, such as problems related to achieving good large area uniformity and accurate thickness control" (See paragraph [0012]). *Aaltonen et al.* does not disclose or suggest using bis(2,4-dimethylpentadienyl) ruthenium in the ALD process.

To solve the ruthenium precursor deficiencies of *Aaltonen et al.*, the Examiner has relied upon the teaching of *Kawano et al.* *Kawano et al.*, contrary to the teachings of *Aaltonen et al.*, discloses a CVD process for forming a ruthenium-containing thin film. (See col. 3, lines 17-22). *Kawano et al.* utilizes a half-sandwich organometallic ruthenium compound in the CVD method (See col. 7, l. 40-44). The half-sandwich organometallic ruthenium compound may be represented by the following formula:

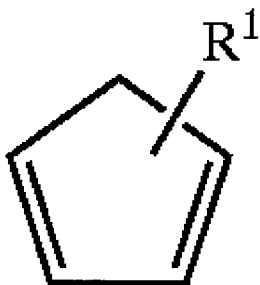


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The half-sandwich organometallic ruthenium compound may be formed by “reacting an open ruthenocene...in a solvent in the presence of zinc with a cyclopentadiene...to thereby produce a half-sandwich organometallic ruthenium compound represented by the general formula (1).” (See col. 3, lines 65 – col. 4, lines 25). The open ruthenocene is represented by the following general formula:



The cyclopentadiene is represented by the following general formula:



Thus, the half-sandwich organometallic ruthenium compound precursor used in the CVD process of *Kawano et al.* also is not bis(2,4-dimethylpentadienyl) ruthenium as recited in claims 11, 54, and 55. The precursor used to synthesize the half-sandwich organometallic ruthenium compound precursor may be bis(2,4-dimethylpentadienyl) ruthenium if one of ordinary skill in the art selects the proper R^2 , R^3 , and R^4 groups from a laundry list of possibilities, but such ruthenium compound is never exposed to the substrate in *Kawano et al.* Applicant respectfully submits that one of ordinary skill, when confronted with *Kawano et al.*, would utilize the half-sandwich organometallic ruthenium compound as a ruthenium precursor. Applicant respectfully submits that one

of ordinary skill in the art, when confronted with *Kawano et al.*, would not utilize the bis(pentadienyl) ruthenium compound as a precursor in a deposition process. Applicant additionally respectfully submits that one of ordinary skill in the art would not select the specific ruthenium compound of bis(2,4-dimethylpentadienyl) ruthenium from a laundry list of possibilities absent hindsight. Therefore, Applicant respectfully submits that utilizing the bis(pentadienyl) ruthenium compound of *Kawano et al.* in the ALD process of *Aaltonen et al.* is not obvious.

Regarding the reducing gas, the Examiner has admitted that both *Aaltonen et al.* and *Kawano et al.* “do not explicitly teach using the combination of ammonia and atomic hydrogen as a reducing agent.” (See Final Office Action mailed April 8, 2008, page 5). The Examiner proceeds to rely upon reducing agents disclosed in Applicant’s specification by state that Applicant “admits that reducing agents such as ammonia, atomic hydrogen, etc. and combinations thereof are traditional reducing agents” (See Final Office Action mailed April 8, 2008, page 5).

Applicant’s disclosure states “[s]uitable reducing gases may include traditional reductants, for example, hydrogen (e.g., H_2 or atomic-H), ammonia (NH_3) ...” (See paragraph [0068]). Applicant respectfully submits that even if the reducing gases disclosed in Applicant’s specification are considered well known and/or traditional, one of ordinary skill in the art would not modify *Aaltonen et al.* to utilize such reducing gases.

Aaltonen et al. is directed to utilizing oxygen containing gas as a reducing gas as opposed to any other reducing gases. *Aaltonen et al.* states:

Surprisingly we have now found that oxygen, in particular oxygen in molecular form, is capable of reducing noble metal compounds into elemental form. High, quality metal thin films can be deposited by utilizing reactions between the metal precursor and oxygen. This is surprising, since oxygen is usually considered an oxidizing source chemical in ALD and even as such an agent its reactivity is usually only modest at temperatures below 500°C.

(See paragraph [0019]). Thus, *Aaltonen et al.* teaches using a specific reducing gas. Applicant respectfully submits that changing the reducing gas of *Aaltonen et al.*, as proposed by the Examiner, would destroy the teachings of *Aaltonen et al.* Therefore, Applicant respectfully submits that the Examiner's proposed modification of *Aaltonen et al.* is not obvious.

Therefore, *Aaltonen et al.* and *Kawano et al.*, alone or in combination, do not teach, show, or suggest a method for forming a ruthenium material on a substrate surface within a process chamber, sequentially comprising exposing a substrate to bis(2,4-dimethylpentadienyl) ruthenium to form a ruthenium-containing film on the substrate, purging the process chamber with a purge gas, exposing a reducing gas comprising ammonia to the ruthenium-containing film while forming a ruthenium layer thereon, and purging the process chamber with the purge gas, as recited in claim 11, and claims dependent thereon. Withdrawal of the rejection is respectfully requested.

Additionally, *Aaltonen et al.* and *Kawano et al.*, alone or in combination, do not teach, show, or suggest a method for forming a ruthenium material on a low-k material disposed on a substrate surface, comprising positioning a substrate comprising a low-k layer disposed thereon within a process chamber, heating the substrate to a temperature within a range from about 200°C to about 400°C, exposing the low-k layer to bis(2,4-dimethylpentadienyl) ruthenium to form a ruthenium-containing compound film thereon, purging the process chamber with a purge gas, exposing the ruthenium-containing compound film to a reducing gas comprising ammonia and atomic hydrogen while forming a ruthenium layer on the low-k layer, and purging the process chamber with the purge gas, as recited in claim 54, and claims dependent thereon. Withdrawal of the rejection is respectfully requested.

Also, *Aaltonen et al.* and *Kawano et al.*, alone or in combination, do not teach, show, or suggest a method for forming a ruthenium material on a barrier material layer disposed on a substrate surface, comprising positioning a substrate comprising a tantalum-containing barrier layer disposed thereon within a process chamber, heating the substrate to a temperature within a range from about 200°C to about 400°C, exposing the tantalum-containing barrier layer to bis(2,4-dimethylpentadienyl) ruthenium while forming a ruthenium-containing compound film thereon, purging the process

chamber with a purge gas, exposing the ruthenium-containing compound film to a reducing gas comprising ammonia and atomic hydrogen while forming a ruthenium layer on the tantalum-containing barrier layer, and purging the process chamber with the purge gas, as recited in claim 55, and claims dependent thereon. Withdrawal of the rejection is respectfully requested.

C. *Aaltonen et al.* and *Kawano et al.* do not render claims 36-38, 40-42, 44-46, 48-51, 53, and 64-66 obvious

Claims 36-38, 40-42, 44-46, 48-51, 53, and 64-66 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over U.S. Patent Application Publication No. 2003/0165615 to *Aaltonen et al.* in view of U.S. Patent No. 6,605,735 to *Kawano et al.*

Aaltonen et al. discloses “placing a substrate in a reaction chamber within a reactor,” “providing a vaporized noble metal precursor into the reaction chamber to form a single molecular layer of the precursor on the substrate,” “removing excess vaporized precursor from the reaction chamber”, “providing a second reactant gas comprising oxygen to the reaction chamber such that the oxygen reacts with the precursor on the substrate,” and “removing excess reactant gas and reactant by-products from the reaction chamber.” (See paragraph [0021]). *Aaltonen et al.* performs an ALD method (See paragraph [0034]) and recognizes “the general limitations of the CVD method, such as problems related to achieving good large area uniformity and accurate thickness control” (See paragraph [0012]).

Kawano et al., contrary to the teachings of *Aaltonen et al.*, discloses a CVD process for forming a ruthenium-containing thin film. (See col. 3, lines 17-22).

Regarding the reducing gas, the Examiner has admitted that both *Aaltonen et al.* and *Kawano et al.* “do not explicitly teach using the combination of ammonia and atomic hydrogen as a reducing agent.” (See Final Office Action mailed April 8, 2008, page 5). The Examiner proceeds to rely upon reducing agents disclosed in Applicant’s specification by state that Applicant “admits that reducing agents such as ammonia, atomic hydrogen, etc. and combinations thereof are traditional reducing agents” (See Final Office Action mailed April 8, 2008, page 5).

Applicant’s disclosure states “[s]uitable reducing gases may include traditional reductants, for example, hydrogen (e.g., H₂ or atomic-H), ammonia (NH₃) ...” (See paragraph [0068]). Applicant respectfully submits that even if the reducing gases disclosed in Applicant’s specification are considered well known and/or traditional, one of ordinary skill in the art would not modify *Aaltonen et al.* to utilize such reducing gases.

Aaltonen et al. is directed to utilizing oxygen containing gas as a reducing gas as opposed to any other reducing gases. *Aaltonen et al.* states:

Surprisingly we have now found that oxygen, in particular oxygen in molecular form, is capable of reducing noble metal compounds into elemental form. High, quality metal thin films can be deposited by utilizing reactions between the metal precursor and oxygen. This is surprising, since oxygen is usually considered an oxidizing source chemical in ALD and even as such an agent its reactivity is usually only modest at temperatures below 500°C.

(See paragraph [0019]). Thus, *Aaltonen et al.* teaches using a specific reducing gas. Applicant respectfully submits that changing the reducing gas of *Aaltonen et al.*, as proposed by the Examiner, would destroy the teachings of *Aaltonen et al.* Therefore, Applicant respectfully submits that the Examiner's proposed modification of *Aaltonen et al.* is not obvious.

Therefore, *Aaltonen et al.* and *Kawano et al.*, alone or in combination, do not teach, show, or suggest a method for forming a ruthenium material on a substrate surface, comprising positioning a substrate within a process chamber, exposing the substrate to a ruthenium-containing compound comprising ruthenium and at least one open chain dienyli ligand while forming a ruthenium-containing compound film thereon, purging the process chamber with a purge gas, exposing the ruthenium-containing compound film to a reducing gas comprising ammonia and hydrogen gas while forming a ruthenium layer on the substrate, and purging the process chamber with the purge gas, as recited in claim 36, and claims dependent thereon. Withdrawal of the rejection is respectfully requested.

Also, *Aaltonen et al.* and *Kawano et al.*, alone or in combination, do not teach, show, or suggest a method for forming a ruthenium material on a low-k material disposed on a substrate surface, comprising positioning a substrate comprising a low-k layer disposed thereon within a process chamber, heating the substrate to a temperature within a range from about 200°C to about 400°C, exposing the low-k layer to a ruthenium-containing compound comprising ruthenium and at least one open chain

dienyl ligand while forming a ruthenium-containing compound film thereon, purging the process chamber with a purge gas, exposing the ruthenium-containing compound film to a reducing gas comprising ammonia while forming a ruthenium layer on the low-k layer, and purging the process chamber with the purge gas, as recited in claim 44, and claims dependent thereon. Withdrawal of the rejection is respectfully requested.

Conclusion

The Examiner errs in finding that *Aaltonen et al.* in view of *Kawano et al.* render claims 1, 2, 4-7, 9-14, 16, 17, 19, 20, 22-25, 27, 28, 30-33, 35-38, 40-42, 44-46, 48-51, and 53-67 obvious. It is respectfully requested that the Board reverse the findings of the Examiner.

Respectfully submitted,



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Claims Appendix

1. (Previously Presented) A method for forming a ruthenium material on a substrate surface, comprising:

positioning a substrate within a process chamber;

exposing a ruthenium-containing compound to the substrate while forming a ruthenium-containing compound film thereon, wherein the ruthenium-containing compound is selected from the group consisting of bis(dialkylpentadienyl) ruthenium compounds, bis(alkylpentadienyl) ruthenium compounds, bis(pentadienyl) ruthenium compounds, and combinations thereof;

purging the process chamber with a purge gas;

exposing a reducing gas comprising ammonia and atomic hydrogen to the ruthenium-containing compound film on the substrate while forming a ruthenium layer thereon; and

purging the process chamber with the purge gas.

2. (Previously Presented) The method of claim 1, wherein the ruthenium-containing compound comprises at least one alkyl group selected from the group consisting of methyl, ethyl, propyl, butyl, and combinations thereof.

3. (Canceled)

4. (Previously Presented) The method of claim 2, wherein the ruthenium-containing compound is selected from the group consisting of bis(2,4-dimethylpentadienyl)

ruthenium, bis(2,4-diethylpentadienyl) ruthenium, bis(2,4-diisopropylpentadienyl) ruthenium, bis(2,4-ditertbutylpentadienyl) ruthenium, bis(methylpentadienyl) ruthenium, bis(ethylpentadienyl) ruthenium, bis(isopropylpentadienyl) ruthenium, bis(tertbutylpentadienyl) ruthenium, derivatives thereof, and combinations thereof.

5. (Previously Presented) The method of claim 1, wherein the reducing gas further comprises a carrier gas selected from the group consisting of nitrogen gas, argon, and combinations thereof.

6. (Previously Presented) The method of claim 5, wherein the ruthenium layer is formed at a temperature within a range from about 200°C to about 400°C.

7. (Previously Presented) The method of claim 6, wherein a thickness of the ruthenium layer is about 20 Å or less.

8. (Canceled)

9. (Previously Presented) The method of claim 1, wherein the substrate further comprises a barrier layer selected from the group consisting of tantalum, tantalum nitride, tantalum silicon nitride, titanium, titanium nitride, titanium silicon nitride, tungsten, tungsten nitride, and combinations thereof, and the ruthenium layer is deposited on the barrier layer.

10. (Previously Presented) The method of claim 1, wherein the substrate further comprises at least one low-k material selected from the group consisting of silicon dioxide, silicon nitride, silicon oxynitride, carbon-doped silicon oxides, silicon oxide carbide, and combinations thereof, and the ruthenium layer is deposited on the low-k material.

11. (Previously Presented) A method for forming a ruthenium material on a substrate surface within a process chamber, sequentially comprising:

 exposing a substrate to bis(2,4-dimethylpentadienyl) ruthenium to form a ruthenium-containing film on the substrate;

 purging the process chamber with a purge gas;

 exposing a reducing gas comprising ammonia to the ruthenium-containing film while forming a ruthenium layer thereon; and

 purging the process chamber with the purge gas.

12. (Previously Presented) The method of claim 11, wherein the reducing gas further comprises a carrier gas selected from the group consisting of nitrogen gas, argon, and combinations thereof.

13. (Previously Presented) The method of claim 12, wherein the layer is formed at a temperature within a range from about 200°C to about 400°C.

14. (Previously Presented) The method of claim 13, wherein a thickness of the ruthenium layer is about 20 Å or less.

15. (Canceled)

16. (Previously Presented) The method of claim 12, wherein the substrate further comprises a barrier layer comprising a material selected from the group consisting of tantalum, tantalum nitride, tantalum silicon nitride, titanium, titanium nitride, titanium silicon nitride, tungsten, tungsten nitride, and combinations thereof, and the ruthenium layer is deposited on the barrier layer.

17. (Previously Presented) The method of claim 12, wherein the substrate further comprises at least one low-k material selected from the group consisting of silicon dioxide, silicon nitride, silicon oxynitride, carbon-doped silicon oxides, silicon oxide carbide, and combinations thereof, and the ruthenium layer is deposited on the low-k material.

18. (Canceled)

19. (Previously Presented) A method for forming a ruthenium material on a substrate, comprising:

depositing a barrier layer on a substrate during a first ALD process, wherein the barrier layer comprises a material selected from the group consisting of tantalum, tantalum nitride, tantalum silicon nitride, titanium, titanium nitride, titanium silicon nitride, tungsten, tungsten nitride, and combinations thereof; and

exposing the substrate sequentially to a ruthenium-containing compound and a reducing gas comprising ammonia to form a ruthenium layer on the barrier layer during a second ALD process, wherein the ruthenium-containing compound is selected from the group consisting of bis(dialkylpentadienyl) ruthenium compounds, bis(alkylpentadienyl) ruthenium compounds, bis(pentadienyl) ruthenium compounds, and combinations thereof.

20. (Previously Presented) The method of claim 19, wherein the ruthenium-containing compound comprises at least one alkyl group selected from the group consisting of methyl, ethyl, propyl, butyl, and combinations thereof.

21. (Canceled)

22. (Previously Presented) The method of claim 20, wherein the ruthenium-containing compound is selected from the group consisting of bis(2,4-dimethylpentadienyl) ruthenium, bis(2,4-diethylpentadienyl) ruthenium, bis(2,4-diisopropylpentadienyl) ruthenium, bis(2,4-ditertbutylpentadienyl) ruthenium, bis(methylpentadienyl) ruthenium, bis(ethylpentadienyl) ruthenium, bis(isopropylpentadienyl) ruthenium, bis(tertbutylpentadienyl) ruthenium, derivatives thereof, and combinations thereof.

23. (Previously Presented) The method of claim 19, wherein the reducing gas further comprises a carrier gas selected from the group consisting of nitrogen gas, argon, and combinations thereof.

24. (Previously Presented) The method of claim 23, wherein the ruthenium layer is formed at a temperature within a range from about 200°C to about 400°C.

25. (Previously Presented) The method of claim 24, wherein a thickness of the ruthenium layer is about 20 Å or less.

26. (Canceled)

27. (Previously Presented) A method for forming a ruthenium film on a dielectric material disposed on a substrate surface, comprising:

positioning a substrate comprising a dielectric layer thereon within a process chamber;

exposing a ruthenium-containing compound to the dielectric layer while forming a ruthenium-containing compound film thereon, wherein the ruthenium-containing compound is selected from the group consisting of bis(dialkylpentadienyl) ruthenium compounds, bis(alkylpentadienyl) ruthenium compounds, bis(pentadienyl) ruthenium compounds, and combinations thereof;

purging the process chamber with a purge gas;

exposing a reducing gas comprising ammonia to the ruthenium-containing compound film on the dielectric layer while forming a ruthenium layer thereon; and

purging the process chamber with the purge gas.

28. (Previously Presented) The method of claim 27, wherein the ruthenium-containing compound comprises at least one alkyl group selected from the group consisting of methyl, ethyl, propyl, butyl, and combinations thereof.

29. (Canceled)

30. (Previously Presented) The method of claim 28, wherein the ruthenium-containing compound is selected from the group consisting of bis(2,4-dimethylpentadienyl) ruthenium, bis(2,4-diethylpentadienyl) ruthenium, bis(2,4-diisopropylpentadienyl) ruthenium, bis(2,4-ditertbutylpentadienyl) ruthenium, bis(methylpentadienyl) ruthenium, bis(ethylpentadienyl) ruthenium, bis(isopropylpentadienyl) ruthenium, bis(tertbutylpentadienyl) ruthenium, derivatives thereof, and combinations thereof.

31. (Previously Presented) The method of claim 27, wherein the reducing gas further comprises a carrier gas selected from the group consisting of nitrogen gas, argon, and combinations thereof.

32. (Previously Presented) The method of claim 31, wherein the ruthenium layer is formed at a temperature within a range from about 200°C to about 400°C.

33. (Previously Presented) The method of claim 32, wherein a thickness of the ruthenium layer is about 20 Å or less.

34. (Canceled)

35. (Previously Presented) The method of claim 27, wherein the dielectric layer comprises at least one low-k material selected from the group consisting of silicon dioxide, silicon nitride, silicon oxynitride, carbon-doped silicon oxides, silicon oxide carbide, and combinations thereof.

36. (Previously Presented) A method for forming a ruthenium material on a substrate surface, comprising:

- positioning a substrate within a process chamber;

- exposing the substrate to a ruthenium-containing compound comprising ruthenium and at least one open chain dienyl ligand while forming a ruthenium-containing compound film thereon;

- purging the process chamber with a purge gas;

- exposing the ruthenium-containing compound film to a reducing gas comprising ammonia and hydrogen gas while forming a ruthenium layer on the substrate; and

- purging the process chamber with the purge gas.

37. (Original) The method of claim 36, wherein the ruthenium-containing compound is selected from the group consisting of bis(dialkylpentadienyl) ruthenium compounds, bis(alkylpentadienyl) ruthenium compounds, bis(pentadienyl) ruthenium compounds, and combinations thereof.

38. (Previously Presented) The method of claim 37, wherein the ruthenium-containing compound comprises at least one alkyl group selected from the group consisting of methyl, ethyl, propyl, butyl, and combinations thereof.

39. (Canceled)

40. (Previously Presented) The method of claim 38, wherein the ruthenium-containing compound is selected from the group consisting of bis(2,4-dimethylpentadienyl) ruthenium, bis(2,4-diethylpentadienyl) ruthenium, bis(2,4-diisopropylpentadienyl) ruthenium, bis(2,4-ditertbutylpentadienyl) ruthenium, bis(methylpentadienyl) ruthenium, bis(ethylpentadienyl) ruthenium, bis(isopropylpentadienyl) ruthenium, bis(tertbutylpentadienyl) ruthenium, derivatives thereof, and combinations thereof.

41. (Previously Presented) The method of claim 36, wherein the ruthenium layer is formed at a temperature within a range from about 200°C to about 400°C.

42. (Previously Presented) The method of claim 41, wherein a thickness of the ruthenium layer is about 20 Å or less.

43. (Canceled)

44. (Previously Presented) A method for forming a ruthenium material on a low-k material disposed on a substrate surface, comprising:

positioning a substrate comprising a low-k layer disposed thereon within a process chamber;

heating the substrate to a temperature within a range from about 200°C to about 400°C;

exposing the low-k layer to a ruthenium-containing compound comprising ruthenium and at least one open chain dienyl ligand while forming a ruthenium-containing compound film thereon;

purging the process chamber with a purge gas;

exposing the ruthenium-containing compound film to a reducing gas comprising ammonia while forming a ruthenium layer on the low-k layer; and

purging the process chamber with the purge gas.

45. (Previously Presented) The method of claim 44, wherein the temperature is within a range from about 300°C to about 350°C.

46. (Previously Presented) The method of claim 45, wherein a thickness of the ruthenium layer is about 20 Å or less.

47. (Canceled)

48. (Previously Presented) The method of claim 44, wherein the low-k layer comprises at least one material selected from the group consisting of silicon dioxide, silicon nitride, silicon oxynitride, carbon-doped silicon oxides, silicon oxide carbide, and combinations thereof.

49. (Previously Presented) The method of claim 44, wherein the reducing gas further comprises hydrogen gas and nitrogen gas.

50. (Previously Presented) The method of claim 44, wherein the ruthenium-containing compound is selected from the group consisting of bis(dialkylpentadienyl) ruthenium compounds, bis(alkylpentadienyl) ruthenium compounds, bis(pentadienyl) ruthenium compounds, and combinations thereof.

51. (Previously Presented) The method of claim 50, wherein the ruthenium-containing compound comprises at least one alkyl group selected from the group consisting of methyl, ethyl, propyl, butyl, and combinations thereof.

52. (Canceled)

53. (Previously Presented) The method of claim 51, wherein the ruthenium-containing compound is selected from the group consisting of bis(2,4-dimethylpentadienyl) ruthenium, bis(2,4-diethylpentadienyl) ruthenium, bis(2,4-diisopropylpentadienyl) ruthenium, bis(2,4-ditertbutylpentadienyl) ruthenium, bis(methylpentadienyl) ruthenium, bis(ethylpentadienyl) ruthenium, bis(isopropylpentadienyl) ruthenium, bis(tertbutylpentadienyl) ruthenium, derivatives thereof, and combinations thereof.

54. (Previously Presented) A method for forming a ruthenium material on a low-k material disposed on a substrate surface, comprising:

- positioning a substrate comprising a low-k layer disposed thereon within a process chamber;

- heating the substrate to a temperature within a range from about 200°C to about 400°C;

- exposing the low-k layer to bis(2,4-dimethylpentadienyl) ruthenium to form a ruthenium-containing compound film thereon;

- purging the process chamber with a purge gas;

- exposing the ruthenium-containing compound film to a reducing gas comprising ammonia and atomic hydrogen while forming a ruthenium layer on the low-k layer; and

- purging the process chamber with the purge gas.

55. (Previously Presented) A method for forming a ruthenium material on a barrier material layer disposed on a substrate surface, comprising:

- positioning a substrate comprising a tantalum-containing barrier layer disposed thereon within a process chamber;

- heating the substrate to a temperature within a range from about 200°C to about 400°C;

- exposing the tantalum-containing barrier layer to bis(2,4-dimethylpentadienyl) ruthenium while forming a ruthenium-containing compound film thereon;

- purging the process chamber with a purge gas;

exposing the ruthenium-containing compound film to a reducing gas comprising ammonia and atomic hydrogen while forming a ruthenium layer on the tantalum-containing barrier layer; and

purging the process chamber with the purge gas.

56. (Previously Presented) The method of claim 5, wherein the reducing gas further comprises nitrogen gas.

57. (Previously Presented) The method of claim 56, wherein the ruthenium-containing compound comprises bis(2,4-dimethylpentadienyl) ruthenium.

58. (Previously Presented) The method of claim 12, wherein the reducing gas further comprises hydrogen gas.

59. (Previously Presented) The method of claim 58, wherein the reducing gas further comprises atomic-hydrogen.

60. (Previously Presented) The method of claim 23, wherein the reducing gas further comprises hydrogen gas.

61. (Previously Presented) The method of claim 60, wherein the reducing gas further comprises atomic-hydrogen.

62. (Previously Presented) The method of claim 31, wherein the reducing gas further comprises hydrogen gas.

63. (Previously Presented) The method of claim 62, wherein the reducing gas further comprises atomic-hydrogen.

64. (Previously Presented) The method of claim 36, wherein the reducing gas further comprises nitrogen gas.

65. (Previously Presented) The method of claim 64, wherein the reducing gas further comprises atomic-hydrogen.

66. (Previously Presented) The method of claim 49, wherein the reducing gas further comprises atomic-hydrogen.

67. (Previously Presented) The method of claim 54, wherein the reducing gas further comprises nitrogen gas.

Evidence Appendix

NONE

Related Proceedings Appendix

NONE